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INCENTIVES AND THE ALLOCATION OF LEGAL COSTS:

Products Liability

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Number 303 July, 1982

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Abstract

Incentives and the Allocation of Legal Costs:
Products Liability

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This paper examines the legal expenditures, the probability of court error and product quality under several rules for allocation legal costs. Equilibrium legal expenditures for the plaintiff and defendant are derived under each rule and the effect of a change on the equilibrium expenditures is derived. It is found that when the proportion of legal costs paid by a losing party increases, the expenditures of the party which should win increase and under certain assumptions, the accuracy of the decision also increases. The suit and settlement decisions are also examined, and risk aversion is discussed. Finally, conditions under which the equilibrium product quality increases as the proportion of costs paid by the losing party increase are derived.

I. Introduction:

The primary purpose of this paper is to examine the manufacturer's incentive to produce a high quality product, when litigation is costly and the court has imperfect information about the quality of the product in question. The information received by the court will depend on the expenditures of the consumer and producer in presenting their cases. These will depend on the allocation of legal costs. In this paper, product quality is examined under two systems of allocating legal costs. In the first system, the American system, each party will pay his own legal costs, while under the second system, the English system, the losing party will pay all legal costs. In addition, a general system in which the losing plaintiff (defendant) will pay some proportion of the defendant's (plaintiff's) legal costs is discussed.

Two issues are examined here. First, the plaintiff's and defendant's legal expenditures are derived under the English and American systems. It is found that the party with a valid case will have higher legal expenditures under the English system and conditions are derived under which the probability of court error decreases as the proportion of costs paid by losing plaintiff or defendant increases. However, it is also found that if the plaintiff is very risk averse, increasing the proportion of costs paid by a losing plaintiff may result in an increase in the probablity of error.

In addition, the incentives for settlement and the incentives to bring suit are examined.[1] It is found that when legal costs are not fixed, there are two effects of a change in the rule on the probability that the plaintiff and defendant will settle. As discussed by Shavell [1982], we see that when the proportion of legal costs paid by a losing party increases, there is a decrease in the total expected legal costs due to differences in the estimates of the probability that the plaintiff will win. In addition, we see that total legal costs may increase, and that will encourage settlement,

given suit. The effect of a change in the rule on the probability that the plaintiff will bring suit also depends on whether the effect of the change in expenditures is greater than the effect of the change in the share of the costs paid by the plaintiff.

Finally, conditions are derived under which a change in the system will result in an increase in the producer's level of care.

Assumptions and Definitions: The system in effect is assumed to be strict liability with defect. The manufacturer is liable if the product is found to be defective. The probability that the product is actually defective will depend on the care or precaution (quality control) used by the manufacturer. If the manufacturer's per unit expenditures on care is x, the proportion of output which is actually defective is m(x). If the manufacturer chooses a higher level of precaution, the proportion of defective output declines, but it declines at a diminishing rate, $m'(x)<0$, $m''(x)>0$.

The output is either defective (D), or non-defective (N). If the output is defective, there is a probability, α, that it will cause an accident with cost, C. If the output is non-defective, there is a probability, β, that there will be a similar accident. It is assumed that α is greater than β.

If an accident occurs and the plaintiff brings suit, it is assumed that the plaintiff and defendant can determine whether the product was defective. The expenditures of each party will depend on the system for allocating legal costs and the quality of the output. Let A denote the American system, and E, the English system. The plaintiff's equilibrium litigation costs for a defective (non-defective) product, under system J, will be denoted π^J ($\bar{\pi}^J$). Similarly, the defendant's expenditures will be denoted $\delta^J$and $\bar{\delta}^J$. The probability that the plaintiff will win, if the product is defective will be denoted $P^{\Pi}(\pi,\delta)$. If the product is not defective, the probability that the plaintiff will win is $\bar{P}^{\Pi}(\pi,\delta)$. Similarly, the probabilty the the defendant

will win, given defective output, is $P^{\Delta}(\pi,\delta)$ and the probability the defendant will win, given that the output is not defective is $\bar{P}^{\Delta}(\pi,\delta)$. It is assumed that the probability of either party winning, given product quality, is a function of legal expenditures for each and not the rule for allocating legal costs. It is assumed that when the plaintiff (defendant) increases legal expenditures, the probability of winning increases at a diminishing rate, i.e., that $P^{\Pi}_{\pi}>0$, $\bar{P}^{\Pi}_{\pi}>0$, $P^{\Delta}_{\delta}>0$ and $\bar{P}^{\Delta}_{\delta}>0$, and that $P^{\Pi}_{\pi\pi}<0$, $\bar{P}^{\Pi}_{\pi\pi}<0$, $P^{\Delta}_{\delta\delta}<0$, and $\bar{P}^{\Delta}_{\delta\delta}<0$. It is also assumed that as the party with a valid case increases his expenditures, the marginal return to the other party's expenditures decreases, i.e., that $P^{\Delta}_{\pi\delta} = -P^{\Pi}_{\pi\delta} < 0$, and $\bar{P}^{\Pi}_{\pi\delta} < 0$.

In Sections 2 and 3, the equilibrium litigation expenditures for risk neutral and risk averse plaintiffs and for risk neutral defendants are derived for the English and American systems. It is shown that if the plaintiff is risk neutral and if the product is defective (non-defective), the consumer's (producer's) litigation costs are higher under the English system than under the American system. The probabilities of Type I and Type II error under each system are compared and the effect of plaintiff risk aversion is examined. In Sections 4 and 5, the settlement and litigation decisions are examined and in Section 6, the producer's quality decisions under the two systems are compared.

II. Litigation Costs under the English and American Systems:

The American System: When the plaintiff and defendant each pay their own litigation costs, the risk neutral plaintiff will the maximize his expected net award:

[2.1] $$\max_{\pi} \; P^{\Pi}(\pi,\delta)C - \pi.$$

where the size of the award is C, the plaintiff's accident costs.

The plaintiff's first order condition is:

[2.2] $$P^{\Pi}_{\pi}(\pi,\delta)C = 1,$$

i.e., he will purchase additional legal services as long as the marginal expected award is greater than the increase in legal costs. The plaintiff's reaction function, $\Pi^{A}(\delta)$, can be derived, and it is seen that if the product is defective, the plaintiff will purchase additional legal services whenever δ increases.[2] It can also be shown that if the product is not defective, the plaintiff will reduce his expenditures when δ increases.

Similarly, the risk neutral defendant will minimize the sum of his litigation costs plus the expected award:

[2.3] $$\min_{\delta} \; P^{\Pi}(\pi,\delta)C + \delta.$$

The defendant's reaction function, $\Delta^{A}(\pi)$, is given by his first order condition:

[2.4] $$P^{\Pi}_{\delta}(\pi,\delta)C + 1 = 0,$$

i.e., he will purchase additional legal services as long as the reduction in the expected award is greater than the increase in legal costs. It can be shown that, if the product is defective, the defendant's reaction function is downward sloping, i.e., $\Delta^{A}_{\pi}(\pi) < 0$.[3] Similarly, if the product is not defective, his reaction function is upward sloping, i.e., $\bar{\Delta}^{A}_{\pi}(\pi) > 0$.

The equilibrium litigation costs are at the intersection of the two reaction curves.

The English System: When the losing party pays both legal fees, the risk neutral plaintiff will maximize his expected award net of his expected legal costs, the probability of losing times total legal costs:

$$[2.5] \qquad \max_{\pi} \quad P^{\Pi}(\pi,\delta)C - (1-P^{\Pi}(\pi,\delta))[\pi+\delta].$$

His first order condition is:

$$[2.6] \qquad P^{\Pi}_{\pi}(\pi,\delta)[C+\pi+\delta] = 1-P^{\Pi}(\pi,\delta).$$

The left hand side of [2.6] is the marginal expected benefit due to an increase in the probability of winning. It is the increase in the expected award plus the reduction in expected legal costs due to the decrease in the probability that he will lose and therefore pay both legal fees. The right hand side of [2.6] is the expected cost of purchasing additional legal services, the increase in total legal costs times the probability he will lose. This first order condition gives the plaintiff's reaction function under the English system, $\Pi^{E}(\delta)$.

Similarly, the defendant's reaction function under the English system, $\Delta^{E}(\pi)$, can be derived. He will minimize the sum of the expected award plus his expected litigation costs:

$$[2.7] \qquad \min_{\delta} \quad P^{\Pi}(\pi,\delta)[C+\pi+\delta].$$

His reaction function is given by his first order condition:

$$[2.8] \qquad -P^{\Pi}_{\delta}(\pi,\delta)[C+\pi+\delta] = P^{\Pi}(\pi,\delta).$$

The left hand side of [2.8] is the marginal reduction in expected liability and legal costs due to a reduction in the probability the plaintiff will win. The right hand side of [2.8] is the defendant's expected marginal cost of legal services.

By totally differentiating the first order conditions, we see that the two reaction functions have opposite signs. If the product is defective, the plaintiff's reaction function is an increasing function of δ, while if the product is not defective, the plaintiff's reaction function is a decreasing function of the defendant's expenditures.[4]

A Comparison of the English and American Systems: By comparing condition [2.6] with condition [2.2], it can be seen that given any level of expenditures by the defendant, the plaintiff will purchase more legal services with the English system than with the American system. Similarly, the defendant's reaction functions under each system can be compared. These comparisons are summarized in Proposition 1.

Proposition 1:

The plaintiff's (defendant's) reaction function under the English system lies to the right (above) his reaction function under the American system, i.e., $\Pi^E(\delta)>\Pi^A(\delta)$, for all δ, and $\Delta^E(\pi)>\Delta^A(\pi)$, for all π.[5]

The explanation is straightforward. Under the English system, the expected marginal cost of legal services is less than under the American system, since the probability that the litigant will pay these expenses under the English system is less than one. Also, under the English system, the expected marginal benefit for legal services is higher for the plaintiff (defendant), since the gain is the increase in the probability of receiving (not paying) the award plus the decrease in the probability of paying all legal costs. Under the American system, only the award is at stake.

Using the reaction functions defined above, the equilibrium legal expenditures given product quality for the plaintiff and defendant can be compared under the English and American systems.

It is seen that with the English system, the plaintiff's legal expenditures are higher than with the American system, if the output is

defective. This is clear from the reaction functions in Figure 1. In addition, it is seen that, if the product is not defective, the defendant's legal expenditures are higher under the English system than under the American system. (See Figure 2.) These results are summarized in Proposition 2.

<u>Proposition 2:</u>

If the product is defective, i.e., if $P^{\Pi}_{\delta\pi} > C^{-2}$, then the risk neutral plaintiff will have higher legal expenditures under the English system than under the American system.

Similarly, if the product is not defective, i.e., if $\bar{P}^{\Pi}_{\delta\pi} < -C^{-2}$, then the risk neutral defendant will have higher legal expenditures under the English system than under the American system.

In addition, the relationship between the equilibrium probability that the plaintiff will win and the proportion of legal expenses paid by the losing party can be derived. In Proposition 3, conditions are derived under which the probability that the plaintiff will win (lose) increases when there is an increase in the share of legal costs shifted, if the product is (is not) defective. If these conditions hold, the probability of error declines as the proportion of legal costs paid by the losing party increases.

<u>Proposition 3:</u>

If the product is defective, and if $-\frac{P^{\Pi}_{\pi\delta}}{P^{\Pi}_{\pi\pi}} > -\frac{P^{\Pi}_{\delta}}{P^{\Pi}_{\pi}}$, i.e., if the plaintiff's reaction function under the American system is flatter than the isoprobability curve, the probability that the plaintiff will win increases when the proportion of legal costs paid by the losing party increases.

Similarly, if the product is not defective, and if $-\frac{\bar{P}^{\Pi}_{\pi\delta}}{\bar{P}^{\Pi}_{\delta\delta}} > -\frac{\bar{P}^{\Pi}_{\pi}}{\bar{P}^{\Pi}_{\delta}}$, i.e., if the defendant's reaction function under the American system is steeper than the isoprobability curve, we see that the probability that the defendant will win increases when the proportion of legal costs paid by the losing party increases.

These are then sufficient conditions for the probability of Type I and Type II error to decrease when the share of legal costs shifted increases.

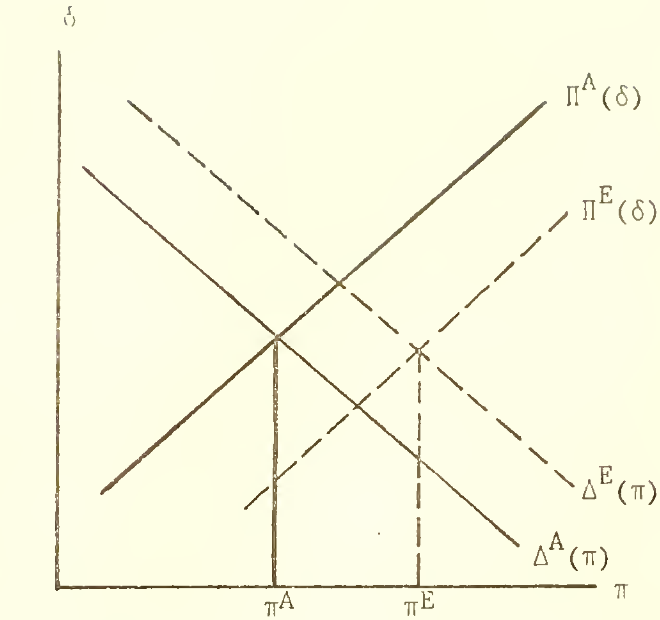

Figure 1: Defective Output: Expenditures under the English and American Systems.

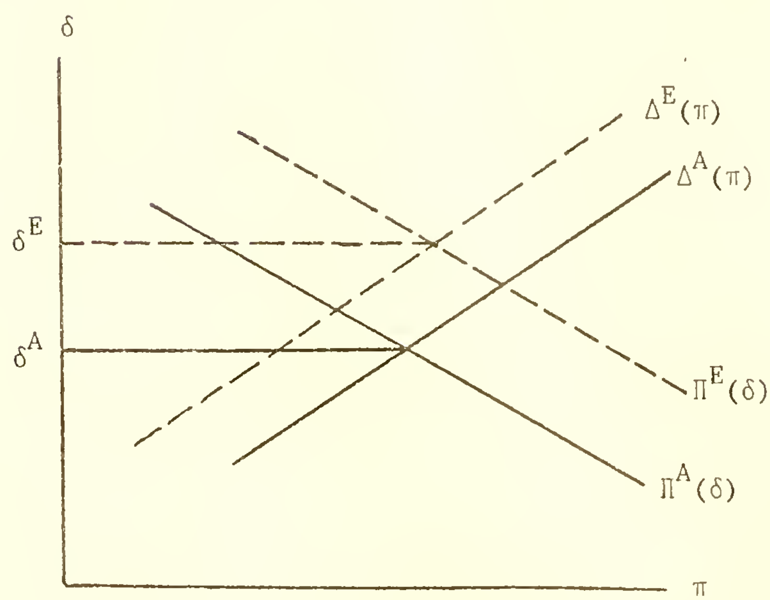

Figure 2: Non-defective Output: Expenditures under the English and American Systems.

III. Litigation Costs: The Risk Averse Plaintiff

Consider a system for the allocation of legal costs in which the proportion of the plaintiff's legal costs paid by a losing defendant is not necessarily equal to the proportion of the defendant's legal costs paid by a losing plaintiff. Let σ be the proportion of the plaintiff's costs paid by the losing defendant and let τ be the proportion of the defendant's costs paid by the losing plaintiff. We will also consider a system in which λ is the proportion of the winning party's costs paid by the losing party, i.e., in which $\sigma=\tau=\lambda$. If $\lambda=0$, this is equivalent to the American system, while if $\lambda=1$, this is equivalent to the English system.

The risk averse plaintiff's expected utility is then:

$$[3.1] \quad \Sigma(\pi,\delta) = P^{\Pi}(\pi,\delta)U(y-(1-\sigma)\pi) + P^{\Delta}(\pi,\delta)U(y-C-\pi-\tau\delta),$$

where U(X) is the plaintiff's von Neumann-Morgenstern utility function and y is his income. By differentiating [3.1] with respect to π, we get the plaintiff's reaction function:

$$[3.2] \quad P^{\Pi}_{\pi}(\pi,\delta)\left[U(y-(1-\sigma)\pi)-U(y-C-\pi-\tau\delta)\right] = (1-\sigma)P^{\Pi}U'(y-(1-\sigma)\pi)+P^{\Delta}U'(y-C-\pi-\tau\delta)$$

The left hand side of [3.2] is the expected utility gain due to an increase in the probability the plaintiff will win. The right hand side of [3.2] is the expected marginal disutility of an increase in expenditures.

Using this system, we will examine first, the effect of risk aversion on the probability of error when $\sigma=1$, and then we will examine how the probability of error changes with changes in σ, τ and λ, as a function of the plaintiff's measure of risk aversion.

A Special Case: The Effect of Risk Aversion when σ = 1. When the losing defendant pays all the winning plaintiff's legal costs, it is seen that as the plaintiff's risk aversion increases, the plaintiff's reaction

curve shifts to the left. If the assumptions in Proposition 3 hold, it is then seen that when the plaintiff becomes more risk averse, the probability, given suit, that the plaintiff will win when the product is defective and the probability that the defendant will win, given suit, when the product is not defective both fall. The effect of risk aversion on the plaintiff's reaction function and on the equilibrium Type I and Type II error are examined in Proposition 4.

Proposition 4: As the plaintiff's risk aversion increases and when the losing defendant pays all the winning plaintiff's legal costs, i.e., when $\sigma=1$, the plaintiff's reaction function will shift to the left as the plaintiff's risk aversion increases. The probability that a defective product is not found to be defective increases, and if the assumptions in Proposition 3 hold, the probability that a non-defective product is found to be defective also increases.

The reason the reaction function shifts in this direction can be demonstrated by examining the effect of a change in expenditures on the distribution of outcomes along the risk neutral plaintiff's reaction function. On this plaintiff's reaction curve, it is seen that the expected net award is maximized. Since the plaintiff's first order condition holds at $\Pi(\delta)$, we see that a small decrease in his expenditures will not change his expected net award. A move from $\Pi(\delta)-\varepsilon$ to $\Pi(\delta)$ is, however, a mean preserving spread [Rothschild and Stiglitz, p. 227-231] and therefore the risk averse plaintiff will prefer the decrease in litigation costs and the reaction function of the risk averse plaintiff will lie to the left of the reaction of the risk neutral plaintiff.

In Figures 3 and 4, we have graphed the equilibrium legal expenditures with risk neutral and risk averse plaintiffs for defective and non-defective output. In Figure 3, it is seen that when the product is defective, as the plaintiff becomes more risk averse, the equilibrium legal expenditures of the

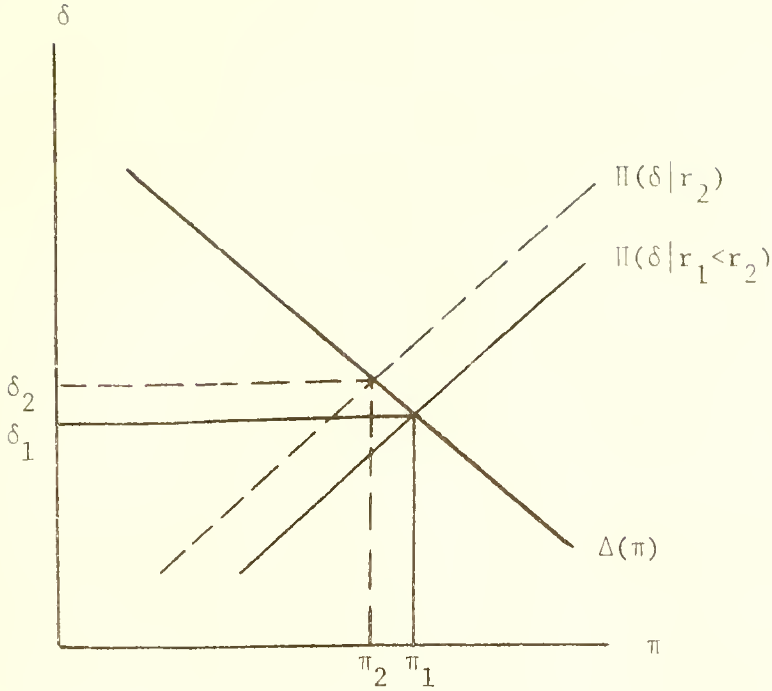

Figure 3: Equilibrium legal expenditures and risk aversion when the losing defendant pays all legal costs: Defective Output.

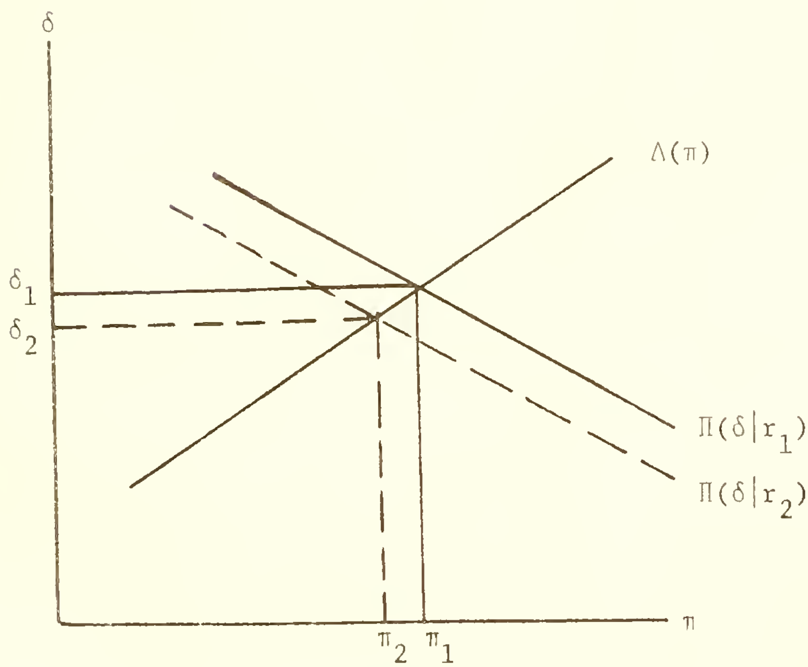

Figure 4: Equilibrium Legal expenditures and risk aversion when the losing defendant pays all legal costs: Non-defective output.

plaintiff fall, and the defendant's expenditures rise. It is clear that as the plaintiff's risk aversion, r, increases, the probability that the plaintiff will win falls. In figure 4, it is seen that if the product is not defective, as the plaintiff's risk aversion increases, the equilibrium expenditures move to the left along $\Delta(\pi)$. Using the second assumption in Proposition 3, we see that the probability that the plaintiff will win increases.

Risk aversion: The General Case. In this section, we will examine the risk averse plaintiff's reaction functions under different rules for the allocation of legal costs. First we will examine the effect of an increase in the proportion of the plaintiff's legal costs paid by a losing defendant, and then we will consider an increase in the defendant's legal costs paid by a losing plaintiff.

If we increase the proportion of legal costs paid by a losing defendant, we see that the risk averse plaintiff's reaction function will shift to the right. There are two effects involved when σ is increased. First, as with the risk neutral plaintiff, we see that the risk averse plaintiff increases his expenditures in response to the reduction in the expected cost of legal expenditures and to the increase in the gross award. In addition, we see that when σ is increased, there is a decrease in the marginal disutility of expenditures as the winning plaintiff's net award increases.

When there is an increase in the proportion of the legal costs paid by a losing plaintiff, the effect on the plaintiff's reaction function is ambiguous. There is an increase due to the increase in the cost of losing, and a decrease in expenditures due to the increased risk. These results are derived in Proposition 5.

Proposition 5: When there is an increase in σ, the reaction curve for a risk averse plaintiff will shift to the right. If there is an increase in τ, the reaction curve will shift to the right if the plaintiff's risk aversion at L is below some critical level, R*, and it will shift to the left if the risk aversion at L is above R*.

Now we will examine the change in the equilibrium litigation costs when σ and τ are increased. We see that if the plaintiff is risk averse, his reaction curve will shift to the right with an increase in σ. Also, it is clear that when σ is increased, the risk neutral defendant's reaction curve will shift up. Using the same procedure as in Proposition 3, it is easy to show that when the assumptions in Proposition 3 hold, the probability of Type I and Type II error will decline when σ is increased. In addition, if the plaintiff's risk aversion at L is less than R*, it is straightforward to show that the probability of error will decline with an increase in τ. It follows that if r(L) is less than R*, the probability of error, when these assumptions hold declines with increases in λ. If, however, the plaintiff is very risk averse, r(L)>R*, we see that an increase in τ or λ may result in an increase in Type I and/or Type II error. These results are summarized in Proposition 6.

Proposition 6: If the plaintiff is risk averse, but the risk aversion at L is less than R*, then an increase in λ, σ or τ will result in a decrease in Type I and Type II error.

If the plaintiff's risk aversion at L is above R*, an increase in σ will result in a decrease in Type I and Type II error, but an increase in τ will result in an increase in the probability the defendant will win if the product is defective (Type I error) and may result in an increase in Type II error. The defendant's expected cost, given suit is a decreasing function of τ. Similarly, if r(L)>R*, an increase in λ may result in an increase in Type I and/or Type II error.

IV. Out of Court Settlement:

Under the American system, the case will be brought to trial only if the plaintiff's estimate of the expected award exceeds the defendant's estimate by more than their estimate of total legal costs with this rule. Under the English system, the difference in the expected award must exceed the expected legal costs under this system. Under the general system, the difference in the expected award must exceed total equilibrium expected legal costs.

With each rule, it will be assumed that the defendant observes a random variable, Y, which is his estimate of the probability that the output is actually defective. If the defendant observes no output specific information about the product, this probability is simply his prior, m(x).

Similarly, the plaintiff is assumed to have imperfect information about the quality of the product. He will observe a random variable, and on the basis of the observation, he will estimate the probability that the product actually is defective. This probability will be denoted Z.[6]

Both individuals are assumed to have imperfect information about the equilibrium litigation costs. Let $p^1(\lambda)$, $\bar{p}^1(\lambda)$, $d^1(\lambda)$ and $\bar{d}^1(\lambda)$ denoted the plaintiff's estimate of his and the defendant's equilibrium expenditures given product quality, and let $p^2(\lambda)$, $\bar{p}^2(\lambda)$, $d^2(\lambda)$ and $\bar{d}^2(\lambda)$ be the defendant's estimates of equilibrium expenditures. It is assumed that the estimates will increase with changes in σ, τ and λ if and only if equilibrium expenditures increase. The settlement zone is described under the the general system and the effects of increases in σ, τ and λ are examined.

The Risk Neutral Plaintiff: Under the general system , the defendant's expected cost of litigation is the expected award plus the expected legal costs. If the product is defective, his estimate of expected costs is:

$$[4.1] \quad T(\lambda) = P^{\Pi}\big(p^2(\lambda),d^2(\lambda)\big)[C+\sigma p^2(\lambda)+\tau d^2(\lambda)] + (1-\tau)d^2(\lambda).$$

where $\lambda=(\sigma,\tau)$, $P^{\Pi}\big(p^2(\lambda),d^2(\lambda)\big)$ is the plaintiff's estimate of equilibrium

probability that he will win when the product is defective. By differentiating with respect to σ and τ and substituting in the first order conditions, we see that:[7]

$$[4.2]\quad \frac{dT}{d\sigma} = p^2(\lambda)P^{\Pi}\left(p^2, d^2\right) + \frac{\partial p^2}{\partial\sigma} > 0, \text{ and}$$

$$[4.3]\quad \frac{dT}{d\tau} = -d^2(\lambda)P^{\Delta}\left(p^2, d^2\right) + \frac{\partial p^2}{\partial\tau}.$$

The first term on the right hand side of [4.2] is the defendant's estimate of the increase in the plaintiff's expected legal costs paid by a losing defendant, when the losing defendant's share increases. The second term is the change in the defendant's expected costs due to the change in his estimate of the plaintiff's legal expenditures. Since the defendant's expected share of legal costs increases and the plaintiff's estimated legal expenditures increase, the defendant's estimate of expected costs is an increasing function of σ when the product is defective. Similarly, the first term on the right hand side of [4.3] is the increase in his estimate of his share of the plaintiff's legal costs and the second term is the decrease in the expected costs due to the change in the estimate of plaintiff's expenditures.

Similarly, if the product is not defective, it is seen that the defendant's estimate of his expected costs is:

$$[4.4]\quad \bar{T}(\lambda) = \bar{P}^{\Pi}\left(p^2(\lambda), d^2(\lambda)\right)\left[C+\sigma\bar{p}^2(\lambda)+\tau\bar{d}^2(\lambda)\right] + (1-\tau)\bar{d}^2(\lambda),$$

and that:

$$[4.5]\quad \frac{d\bar{T}}{d\sigma} = \bar{p}^2\bar{P}^{\Pi}\left(p^2(\lambda), d^2(\lambda)\right) + \frac{\partial\bar{p}^2}{\partial\sigma}, \text{ and}$$

$$[4.6]\quad \frac{d\bar{T}}{d\tau} = -\bar{d}^2\bar{P}^{\Delta}\left(p^2(\lambda), d^2(\lambda)\right) + \frac{\partial\bar{p}^2}{\partial\tau} < 0.$$

The risk neutral plaintiff's estimated expected wealth if the case is litigated and if the product actually was defective is:

$$[4.7]\quad S(\lambda) = P^{\Pi}\left(p^1(\lambda), d^1(\lambda)\right)\left[y-(1-\sigma)p^1(\lambda)\right] + P^{\Delta}\left[y-C-p^1(\lambda)-\tau d^1(\lambda)\right],$$

By differentiating with respect to σ and τ and substituting in the plaintiff's and defendant's first conditions, we see that:[8]

$$[4.8] \quad \frac{dS}{d\sigma} = p^1 P^{\Pi}\left(p^1(\lambda), d^1(\lambda)\right) - \frac{\partial d^1}{\partial \sigma}, \text{ and}$$

$$[4.9] \quad \frac{dS}{d\tau} = - d^1 P^{\Delta}\left(p^1(\lambda), d^1(\lambda)\right) - \frac{\partial d^1}{\partial \tau}.$$

If the product is not defective, the plaintiff's estimate of his expected net wealth is:

$$[4.10] \quad \bar{S}(\lambda) = \bar{P}^{\Pi}(\bar{p}^1, \bar{d}^1)[y-(1-\sigma)\bar{p}^1(\lambda)] - \bar{P}^{\Delta}(\bar{p}^1, \bar{d}^1)[y-C-\bar{p}^1(\lambda)-\tau\bar{d}^1(\lambda)],$$

By differentiating and simplifying, we see that:

$$[4.11] \quad \frac{d\bar{S}}{d\sigma} = \bar{p}^1 \bar{P}^{\Pi}(p^1, d^1) - \frac{\partial \bar{d}^1}{\partial \sigma}, \text{ and}$$

$$[4.12] \quad \frac{d\bar{S}}{d\tau} = -\bar{d}^1 \bar{P}^{\Delta}(p^1, d^1) - \frac{\partial \bar{d}^1}{\partial \tau}.$$

It is assumed that the case will be settled out of court if the defendant's expected costs exceed the risk neutral plaintiff's expected net award, i.e., the case will be settled if Z is greater than $\tilde{Z}(Y)$, where:

$$[4.13] \quad YT(\lambda) + [1-Y]\bar{T}(\lambda) = \tilde{Z}S(\lambda) + (1-\tilde{Z})\bar{S}(\lambda).$$

By differentiating [4.13] and simplifying, we see that given Y, the plaintiff's critical probability of defect, $\tilde{Z}$, below which he will settle, is a decreasing function of σ if:

$$[4.14] \quad \tilde{Z}[p^1 P^{\Pi}(p^1, d^1) - \bar{p}^1 \bar{P}^{\Pi}(\bar{p}^1, \bar{d}^1)] - Y[p^2 P^{\Pi}(p^2, d^2) - \bar{p}^2 \bar{P}^{\Pi}(\bar{p}^2, \bar{d}^2)] >$$
$$Y \frac{\partial p^2}{\partial \sigma} + (1-Y)\frac{\partial \bar{p}^2}{\partial \sigma} + \tilde{Z}\frac{\partial d^1}{\partial \sigma} + (1-\tilde{Z})\frac{\partial \bar{d}^1}{\partial \sigma}.$$

The left hand side of [4.14] is the reduction in the perceived litigation costs due to the difference in the estimates of the probability of defect. If the estimates of legal expenditures given product quality are similar, it is positive, since at the marginal settlement point, both parties are relatively optimistic, and therefore, they are evaluating the fraction of litigation costs paid by the losing party at less than the total costs. The

left hand side measures the increase in this distortion as σ increases.

The right hand side of [4.14] is the perceived increase in the litigation costs due to the increase in expenditures when σ is increased. Generally, this is also positive. When inequality [4.14] holds, an increase in σ will discourage settlement, since the effect of the undervaluation of expected legal costs exceeds the effect of the increase in expenditures.

The derivation of the effect of an increase in τ and λ is similar. These results are summarized in Proposition 7:

Proposition 7:[9] The probability of settlement will decrease when the proportion of legal costs paid by a losing party increases if the reduction in the perceived costs, due to the differences in the estimates of the probability of defect exceeds their estimate of the increase in expected litigation costs due to the change in the plaintiff's and defendant's incentives given trial.

Settlement: The Risk Averse Plaintiff: Next we will examine the effect of plaintiff risk aversion on the probability of settlement, given the rule for allocating legal costs.

The risk neutral defendant's highest offer is his estimate of the expected cost: $YT(\lambda) + (1-Y)\bar{T}(\lambda)$. When the plaintiff is risk averse, the parties will settle if the plaintiff would prefer this offer to the expected trial outcome, i.e.:

[4.15] $Z\,\Sigma(\lambda) + (1-Z)\,\bar{\Sigma}(\lambda) < U\big(y-C+YT(\lambda)+(1-Y)\bar{T}(\lambda)\big).$

where $\Sigma(\lambda)$ and $\bar{\Sigma}(\lambda)$ are the plaintiff's estimates of his expected utility if he litigates and if the product is defective or non-defective, respectively.

If inequality [4.15] holds at $\tilde{Z}(Y)$, then the risk averse plaintiff will settle more frequently than the risk neutral plaintiff. By substituting in equation [4.13], we see that the risk averse plaintiff will settle more frequently if:

[4.16] $\tilde{Z}\,\Sigma(\lambda) + (1-\tilde{Z})\,\bar{\Sigma}(\lambda) < U\big(y-C+\tilde{Z}S(\lambda)+(1-\tilde{Z})\bar{S}(\lambda)\big).$

It is straightforward to show that inequality [4.15] holds whenever the

plaintiff is risk averse, and therefore:

Proposition 8:[10] Settlement is more likely with a risk averse plaintiff than with a risk neutral plaintiff. In addition, the defendant's expected cost declines as the plaintiff's risk aversion increases.

V. Initiating a Suit:

For each rule for allocating legal costs, there is a critical probability, Z^*, above which the plaintiff will initiate a suit. For the risk neutral potential plaintiff, this is the probability of defect for which the expected value of bringing suit is zero. The expected value of bringing suit will depend on the settlement when settlement is possible. We will begin by examining the case in which the plaintiff receives his expected net award. Other assumptions about settlement are considered in Propositions 9 and 10.

The Risk Neutral Potential Plaintiff: If, when the case is settled, the plaintiff receives his expected net award, the risk neutral plaintiff will litigate if the expected net value of litigation is positive, i.e., he will initiate suit if and only if:

[5.1] $ZS(\lambda) + (1-Z)\bar{S}(\lambda) > y-C.$

By rearranging terms, we see that the potential plaintiff will initiate suit if his estimate of the probability that the product is defective is at least some critical probability, $Z^*(\lambda)$, where:

[5.2] $Z^*\ S(\lambda) + [1-Z^*]\bar{S}(\lambda) = y-C.$

By differentiating [5.2], we can determine the effect of an increase in σ, τ and λ on the litigation decision of the risk neutral potential plaintiff. The effect of a change in the rule will depend on whether the potential plaintiff's expected net award at the critical probability of defect increases or decreases. This is determined by the change in the expected net award for defective and non-defective output and the critical probability of defect. These results are summarized in Proposition 9.

Proposition 9: When settlement is not possible or when in settlement, the plaintiff receives his expected net award, i.e., the defendant gets all the gains to settlement, the following results hold:

If the plaintiff's expected net award when the product is not defective, $\bar{S}(\sigma,\tau)$, is an increasing function of σ, then the propensity to bring suit is an increasing function of σ. If $\bar{S}_{\sigma}(\sigma,\tau)$ is negative, i.e., if when σ is increased, the increase in the defendant's litigation costs exceeds the reduction in the plaintiff's expected share of litigation costs, then the propensity to bring suit may be a decreasing function of σ if the critical probability of defect is sufficiently low.[11]

If $S(\sigma,\tau)$ is a decreasing function of τ, then the propensity to bring suit is a decreasing function of τ. If $S(\sigma,\tau)$ is an increasing function of τ, then the propensity to bring suit may increase as τ increases, if the critical probability if defect is sufficiently high.

The plaintiff's propensity to bring suit may increase or decrease when λ increases.[12] It is shown that when $\bar{P}^{II}$ and P^{II} are both large, the propensity to bring suit will increase, while when these probabilities are low, the propensity to bring suit will decrease.[13]

If, when settlement occurs, the plaintiff receives the defendant's expected costs, then the plaintiff will choose a lower critical probability of defect, bringing suit more frequently than in the above cases, but the effect of a change in σ, τ and λ is similar.

Initiating a Suit: The Risk Averse Potential Plaintiff: The risk averse plaintiff will then initiate suit whenever his estimate of the probability that the product is defective is greater than some critical probability, $Z^*(\lambda)$, where:

[5.3] $\quad Z^*\Sigma + [1-Z^*]\bar{\Sigma} = U(y-C).$

By shifting the plaintiff's utility function to increase the degree of risk aversion, while holding his utility at W and L constant, we can derive the results in Proposition 10:

Proposition 10:[14] A risk averse plaintiff will choose a higher critical probability of defect than a risk neutral plaintiff. The plaintiff's propensity to bring suit is then a decreasing function of risk aversion.

In addition, the conditions under which the risk averse plaintiff will increase his critical probability of defect in response to changes in σ, τ and λ are similar to the conditions derived for the risk neutral plaintiff in Proposition 9.

VI. Precaution and the Allocation of Legal Costs:

In this section, we will examine how the producer's precaution is affected by the rule for allocating legal costs. We will consider first the case in which the distribution of Z given product quality does not depend on the producer's care. This will be examined under three possible assumptions about the settlement outcome. First, we will consider the case in which settlement cannot occur. Then we will examine the producer's incentives when either the plaintiff or the defendant get all the gains from settlement. We will further assume that the estimates of the equilibrium legal expenditures given product quality are unbiased.

In each case, the risk neutral producer will select the level of precaution which minimizes his expected unit costs. These costs will depend on the rule for allocating legal fees, since the probability that the product will be found to be defective and the producer's liability, given its quality, varies with the system in effect. The cost minimizing level of precaution for the general system is derived below.

The risk neutral producer chooses a level of precaution to minimize expected unit costs. Under the general system, his optimization is:

$$[6.1] \qquad \min_{x} \; x + \alpha m(x)V^{i}(x,\lambda) + \beta\big(1-m(x)\big)\bar{V}^{i}(x,\lambda).$$

where $V^{i}(x,\lambda)$ and $\bar{V}^{i}(x,\lambda)$ are the manufacturer's expected costs in case i, given an accident has occurred for defective and non-defective output, respectively.

By differentiating [6.1] with respect to x, we see that the first order condition for the the producer's optimization is:

$$[6.2] \qquad 1 + m'(x)\big[\alpha V^{i}(x,\lambda) - \beta\bar{V}^{i}(x,\lambda)\big] + \alpha m(x)\,\frac{\partial V^{i}}{\partial x} - \beta(1-m(x))\,\frac{\partial \bar{V}^{i}}{\partial x} = 0.$$

Since there are assumed to be diminishing returns to precaution, $m''<0$, it is seen that when the expected cost given quality is not a function of precaution, the cost-minimizing level of precaution is an increasing function of σ if and only if:

$$[6.3] \qquad \alpha \frac{\partial V^i}{\partial \sigma} - \beta \frac{\partial \bar{V}^i}{\partial \sigma} > 0.$$

Precaution and the Allocation of Legal Costs: The risk neutral plaintiff.

Case 1: In this section, we will assume that whenever the plaintiff brings suit, the case will go to trial and that given product quality, the probability of defect does not depend on the producer's precaution.

If settlement is not possible, if the product is defective and if an accident occurs, the producer's expected liability is:

$$[6.4] \qquad V^1(x,\lambda) = E\Big[\int_{Z^{*1}(\lambda)}^{1} T(\lambda)\, dG(Z)\Big],$$

where $G(Z)$ is the distribution of the consumer's estimate of the probability of defect when the product is defective, Z^{*1} is the plaintiff's critical probability of defect above which he will intiate suit and the expected value is taken over estimates of the equilibrium expenditures.

Similarly, if the product is not defective and an accident occurs, the producer's expected liability is:

$$[6.5] \qquad \bar{V}^1(x,\lambda) = E\Big[\int_{Z^{*1}(\lambda)}^{1} \bar{T}(\lambda)\, d\bar{G}(Z)\Big],$$

where $\bar{G}(Z)$ is the distribution of the the consumer's estimates of the probability of defect when the product is not defective. It is assumed that $\bar{G}(Z) \geqslant G(Z)$, for all Z, i.e., the estimates of the probability of defect are higher when the product actually is defective and that $\bar{g}(Z)$ and $g(Z)$ are the associated density functions.

By differentiating equation [6.4] with respect to σ, we see that:

$$[6.6] \qquad \frac{\partial V^1}{\partial \sigma} = E\Big[- \frac{\partial Z^{*1}}{\partial \sigma} T(\lambda) g(Z^{*1}) + \int_{Z^{*1}(\lambda)}^{1} \frac{\partial T}{\partial \sigma}\, dG(Z)\Big].$$

Similarly, by differentiating equation [6.5] with respect to σ, we see that:

$$[6.7] \qquad \frac{\partial \bar{V}^1}{\partial \sigma} = E\left[-\frac{\partial Z^{*1}}{\partial \sigma}\bar{T}(\lambda)\bar{g}(Z^{*1}) + \int_{Z^{*1}(\lambda)}^{1} \frac{\partial \bar{T}}{\partial \sigma}\, d\bar{G}(Z)\right].$$

By substituting [6.6] and [6.7] into [6.3] and observing that when settlement is not possible, the manufacturer's cost given the quality of output does not depend on the probability of defect, we see that:

$$[6.8] \quad \alpha\frac{\partial V^1}{\partial \sigma} - \beta\frac{\partial \bar{V}^1}{\partial \sigma} = E\left[\frac{\partial Z^{*1}}{\partial \sigma}\left[\beta\bar{T}(\lambda)\bar{g}(Z^*)-\alpha T(\lambda)g(Z^*)\right]\right]$$

$$+ E\left[\int_{Z^{*1}}^{1}\left[\alpha g(z)\frac{\partial T}{\partial \sigma} - \beta\bar{g}(z)\frac{\partial \bar{T}}{\partial \sigma}\right]dz\right].$$

The first term on the right hand side of [6.8] is the effect of the change in the plaintiff's propensity to bring suit. Since the defendant's expected liability for a marginal suit is higher for low quality output than for high quality output, it follows that the first term on the right hand side of [6.8] is positive, if when σ increases, the potential plaintiff will bring suit more frequently, i.e., Z^* falls. The second term on the right hand side of [6.8] is the effect on the relative expected liability for high and low quality output. If when σ increases, the plaintiff's expenditures increase more when the product actually is defective, we see that the second term is positive[15], i.e., the difference in the defendant's liability for low and high quality output is higher when σ increases. Proposition 11 follows:

<u>Proposition 11:</u> If settlement is not possible and the consumer's estimate, Z, given quality is not a function of x, then:

If the plaintiff's expenditures increase more for defective output than non-defective output, the producer will increase his level of precaution when σ increases, when (1) an increase in the proportion of legal costs paid by a losing defendant encourages suit, i.e. $\frac{dZ^{*1}}{d\sigma} < 0$, or (2) the effect of the increase in the relative cost of defective output is greater than the effect of the reduction in the propensity to bring suit.

The producer will decrease his level of precaution when τ increases, unless the effect of a larger reduction in the expected cost of non-defective relative to defective output is greater than the effect of the reduction in the plaintiff's propensity to bring suit.[16]

The producer will increase his level of precaution when λ increases if and only if:[17] (1) the plaintiff's propensity to bring suit increases as λ increases or (2) the effect of the change in the relative cost is larger than the effect of the decline in the propensity to bring suit.

Case 2: In this section, we will assume that the plaintiff will get the benefit to settlement, i.e., if the case is settled, the plaintiff will get the defendant's estimate of his expected costs, $YT(\lambda)+(1-Y)\bar{T}(\lambda)$.

As in case 1, when the plaintiff gets the gains from settlement, we see that the defendant's costs given the quality of output do not depend on his level of precaution. This is because precaution enters the conditional problem only in determining the probability of settlement. The manufacturer's costs are not a function of the probability of settlement.

Since the plaintiff will get the gains from settlement, the producer's expected liability costs for defective and non-defective output are:

$$[6.9] \quad V^2(\lambda) = E\left[\int_{Z^{*2}(\lambda)}^{1} T(\lambda)\, dG(Z)\right], \text{ and}$$

$$[6.10] \quad \bar{V}^2(\lambda) = E\left[\int_{Z^{*2}(\lambda)}^{1} \bar{T}(\lambda)\, d\bar{G}(Z)\right].$$

When the plaintiff gets the benefits from settlement, we see that the expected return to bringing suit is higher than in cases 1 and 3 for all allocation rules. In addition, we can derive conditions under which: $\frac{\partial Z^{*2}}{\partial \sigma} > \frac{\partial Z^{*1}}{\partial \sigma}$, i.e., if an increase in σ encourages litigation, the decrease in the critical probability of defect is lower in case 2 than in case 1. Therefore, the effect of the change in the propensity to bring suit would be lower in case 2.[18]

Similarly, we get corresponding results for an increase in τ or λ. The derivation of these results are similar to those of case 1.

Proposition 12: If when settlement is possible, the consumer receives the defendant's expected costs, and if $\pi > \bar{\pi}$, $\delta < \bar{\delta}$, and $P^{\Pi} > \bar{P}^{\Pi}$, a change in the allocation rule will have the following effects:

If the plaintiff's expenditures increase more for defective output than non-defective output, the producer will increase his level of precaution when σ increases when: (1) the propensity to bring suit increases when σ increases or (2) the effect of the increase in the relative cost of defective output is greater than the effect of the reduction in the propensity to bring suit.

The producer will decrease his level of precaution when τ increases unless the effect of the increase in the difference between the expected cost of defective and non-defective output is greater than the effect of the reduction in the propensity to bring suit. The producer will decrease his precaution in response to an increase in τ in case 2 whenever this is the effect in case 1.[19]

The producer will increase his level of precaution in response to an increase in λ if and only if: (1) the plaintiff's propensity to bring suit increases as λ increases or (2) the effect of the change in relative costs is larger than the effect of the decline in the propensity to litigate. The producer will reduce his level of precaution in response to an increase in λ in case 2 whenever this is the result in case 1.

Case 3: In this section, we will assume that the defendant will get the benefit from settlement, i.e., if the case is settled, the plaintiff will collect his expected net award, $ZS(\lambda) + (1-Z)\bar{S}(\lambda)$. It is also assumed that the consumer's estimate of the probability of defect given product quality does not depend on x.

When the defendant will get the gains from settlement, the producer's expected liability costs for defective and non-defective output are:

$$[6.11] \quad V^3(\lambda) = E\left[\int_{Z^{*3}}^{\tilde{Z}^3} [ZS(\lambda) + (1-Z)\bar{S}(\lambda)]\, G(Z) + \int_{\tilde{Z}^3}^{1} T(\lambda)dG(Z) \right], \text{ and}$$

$$[6.12] \quad \bar{V}^3(\lambda) = E\left[\int_{Z^{*3}}^{\tilde{Z}^3} [ZS(\lambda) + (1-Z)\bar{S}(\lambda)]d\bar{G}(Z) + \int_{\tilde{Z}^3}^{1} \bar{T}(\lambda)d\bar{G}(Z) \right].$$

In this case, we see that the defendant's expected costs given product quality does not depend on his level of precaution. When the defendant increases precaution, his estimate of the probability of defect decreases and therefore settlement is more likely: $\tilde{Z}^3(x|\lambda)$ is an increasing function of x.

But since the defendant's expected cost is equal to the plaintiff's expected net award at the critical probability of defect for settlement, we see that there is not direct effect of the change in $\tilde{Z}^3$ on the producer's costs.

Using this result and inequality [6.3], we see that the cost minimizing level of precaution in an increasing function of σ if and only if:

$$[6.13] \quad E[\int_{Z^{*3}}^{\tilde{Z}^3} [Z\frac{\partial S}{\partial\sigma}+(1-Z)\frac{\partial\bar{S}}{\partial\sigma}][\alpha g(Z)-\beta\bar{g}(Z)]dZ] + E[\int_{\tilde{Z}^3}^{1} [\alpha g(Z)\frac{\partial T}{\partial\sigma}-\beta\bar{g}(Z)\frac{\partial\bar{T}}{\partial\sigma}]dZ] > 0.$$

The first term on the left hand side of [6.13] is the change in the expected settlement due to the change in σ. The second term is the change in the expected cost of trial. Unlike cases 1 and 2, a change in the propensity to bring suit will not affect the producer's costs since the marginal suit is settled at no cost.

The results in inequality [6.13] and corresponding expressions for the effects of changes in τ are summarized in Proposition 13.

Proposition 13: When, if the case is settled, the plaintiff receives his expected net award and when the distribution of the consumer's estimate of the probability of defect given product quality does not depend on x, we see that:

If $\pi > \bar{\pi}$, $P^{\Pi} > \bar{P}^{\Pi}$ and $\frac{\partial\delta}{\partial\sigma} > \frac{\partial\bar{\delta}}{\partial\sigma}$, the producer will increase the level of precaution when σ increases if (1) the plaintiff's expected net award (at Z^{*3}) is an increasing function on σ and if (2) the increase in the defendant's expected costs due to the increase in σ is higher when the product is defective than non-defective.

The producer will reduce his level of precaution when τ increases unless the effect of the reduction in his expected costs when the case is settled is less than the effect of a larger reduction in expected costs for non-defective than defective output when the case goes to trial.

Precaution and the Allocation of Legal Costs: The Risk averse plaintiff

In this section, we will briefly consider how plaintiff risk aversion affects the producer's incentives. From Proposition 6, we see that if the plaintiff is risk averse, but r(L) is less than R*, the effects of changes in σ, τ and λ on the equilibrium legal expenditures and the defendant's expected costs are similar to those of the risk neutral plaintiff. But if the plaintiff is very risk averse, we see that his equilibrium expenditures are a decreasing function of τ. In addition, given the assumptions of Proposition 3, we see that the probability of Type I and Type II error are increasing functions of τ, and that the probability of error is higher when the plaintiff is risk averse. By examining equations [5.3] and [5.6], we see that the change in the difference between the cost of defective and non-defective output is less for the risk averse plaintiff. This means that when the plaintiff is risk averse, an increase in τ will not be as effective as when the plaintiff is risk neutral.

The explanation is clear. An increase in σ will reduce the risk involved in the use of the legal system, and therefore be relatively effective in encouraging the risk averse plaintiff to use the system. An increase in τ will increase the risk, and may therefore reduce the effectiveness of the system. Since increasing λ will have both effects, we see that we cannot determine the net effect of this change.

VII. Conclusion:

In this paper, we examined several systems for allocating legal costs. For each system, we determined the equilibrium legal expenditures given trial for the plaintiff and defendant and the probability of Type I and Type II error. These levels of expenditures and error were compared, and the effect of small changes in the rule for allocating legal costs were examined. It was found that when the plaintiff and defendant are both risk neutral, increasing the proportion of the winning defendant's (plaintiff's) litigation costs paid by a losing plaintiff (defendant) will reduce the probability of error. However, if the plaintiff is risk averse, increasing the proportion of the defendant's costs paid by a losing plaintiff may increase the probability of each type of error, while increasing the proposition of the plaintiff's costs paid by a losing defendant will still reduce the probability of Type I and Type II error.

In addition, the plaintiff's incentives to bring suit and the settlement decisions were examined. When legal costs are not fixed, we found an additional effect of a change in the rule. This is related to the change in the perceived expected legal costs as equilibrium expenditures change. Generally, this effect will work in the opposite direction from the effects discussed by Shavell [1982]. Shavell has shown that with litigation costs constant, the probability that the plaintiff will bring suit increases as the proportion of the plaintiff's costs paid by a losing defendant increases. Here, it is shown that the probability that the plaintiff will bring suit may decrease if there is a large increase in the defendant's legal expenditures in response to the increase in the winning plaintiff's total award. Shavell has also shown that given suit, the probability of settlement falls as the proportion of costs paid by the losing party increases. Here, it is shown

that the probability of settlement may increase if the increase in legal expenditures is sufficiently high.

Finally, conditions were derived under which an increase in the proportion of legal costs paid by a losing plaintiff or defendant will result in an increase in the producer's care. It is seen that an increase in the plaintiff's costs paid by a losing defendant is more likely to be effective in increasing the producer's precaution, since the difference in the expected costs of defective and non-defective output is more likely to increase as the probability of court error declines and the cost to the producer of being found liable increases. This is particularly likely if the potential plaintiff is risk averse.

FOOTNOTES

1. Shavell [1982] examines these two effects under the English and American systems when the system in effect does not affect legal expenditures. His conclusions are discussed in footnotes 9, 10, 13 and 14, below.

2. By totally differentiating the plaintiff's reaction function, we see that: $\frac{d\pi}{d\delta} = - P^{\Pi}_{\pi\delta} \,/\, P^{\Pi}_{\pi\pi} > 0$, if the product is defective.

3. By totally differentiating, the defendant's first order condition, [2.4], we see that: $\frac{d\delta}{d\pi} = - P^{\Pi}_{\delta\pi} \,/\, P^{\Pi}_{\delta\delta} < 0$.

4. By totally differentiating the plaintiff's first order condition, we see that the slope of his reaction function is: $\frac{d\pi}{d\delta} = - \frac{P^{\Pi}_{\pi\delta}[C+\pi+\delta]+P^{\Pi}_{\pi}+P^{\Pi}_{\delta}}{P^{\Pi}_{\pi\pi}[C+\pi+\delta] + 2P^{\Pi}_{\pi}}$. The denominator is negative when the plaintiff's second order condition holds. By differentiating the defendant's first order condition, we see that the slope of his reaction function is: $\frac{d\delta}{d\pi} = - \frac{P^{\Pi}_{\pi\delta}[C+\pi+\delta]+P^{\Pi}_{\pi}+P^{\Pi}_{\delta}}{P^{\Pi}_{\delta\delta}[C+\pi+\delta] + 2P^{\Pi}_{\delta}}$, where the denominator is positive when the defendant's second order condition holds. Since both numerators are the same, and they are positive if the product is defective, and negative if the product is not defective, the above results follow.

5. A stronger version of Proposition 1 can be proven. Let λ be the proportion of the winning party's legal costs paid by the losing party. By examining the first order conditions, we see that, given δ, the plain-

tiff's reaction function shifts to the right when there is an increase in the proportion of legal costs shifted, and given π, the defendant's reaction function will shift up with an increase in λ. Proofs of Propositions 1 through 5 are in Appendix B.

6. His estimate of the probability that the output is defective may depend on the proportion of output involved in accidents which is defective, and therefore Z may be a function of x.

7. By differentiating, we see that: $\frac{dT}{d\sigma} = \frac{\partial T}{\partial \sigma} + T_\pi \frac{\partial p^2}{\partial \sigma} + T_\delta \frac{\partial d^2}{\partial \sigma}$. When the defendant's FOC holds, $T_\delta = 0$. By substitution, we see that $T_\pi = S_\pi + 1 = 1$. In addition, we know that if the product is defective, the plaintiff's legal expenditures are an increasing function of σ, and equation [4.2] follows.

8. By differentiating, we see that: $\frac{dS}{d\sigma} = \frac{\partial S}{\partial \sigma} + S_\pi \frac{\partial p^1}{\partial \sigma} + S_\delta \frac{\partial d^1}{\partial \sigma}$. When the plaintiff's FOC holds, $S_\pi = 0$. By substitution, we see that $S_\delta = T_\delta - 1$. The defendant's FOC is: $T_\delta = 0$. Equation [4.8] follows.

9. These results differ from the results in Shavell [1982], where litigation costs are fixed. There it is seen that given that the plaintiff intiated suit, the probability of settlement will decrease as σ, τ and λ increase, since the parties are optimistic and undervalue any costs paid by the losing party. This corresponds to the term on the left hand side of [4.14] and the corresponding inequalities. Here it is seen that when litigation costs depend on the system in effect, the effect of the increase in litigation costs will generally encourage settlement, and if the plaintiff and/or defendant change their expenditures significantly when the portion of legal costs paid by the losing party increases, we see that an increase in the proportion of costs paid by the losing party may result in an increase in the probability of settlement.

10. The first half of the proposition is similar to the result in Shavell, in which he shows that in all four systems, the probability of settlement is higher when the plaintiff is risk averse. Both results follow directly from Jensen's inequality and the fact that the risk neutral plaintiff will maximize the expected net award.

11. By differentiating [5.2] with respect to σ, we see that:

$$[F.11] \qquad \frac{dZ^*}{d\sigma} = - \frac{Z^* \frac{dS}{d\sigma} + (1-Z^*) \frac{d\bar{S}}{d\sigma}}{S - \bar{S}} .$$

The right hand side is negative if $\frac{d\bar{S}}{d\sigma} > 0$, i.e., if the expected value of a suit increases for both defective and non-defective output. If this is the case, the expected value of a suit, given Z, increases as σ increases and therefore Z* decreases, and the plaintiff's propensity to bring suit increases. But, it is also seen that if the expected value of a suit when the product is not defective is a decreasing function of σ, then the right hand side of this equation is negative if Z* is sufficiently high. The effect of an increase in τ can be derived using the same procedure.

12. By differentiating [5.2] with respect to λ and substituiting in equations [4.8,9,11 and 12], we see that: $\frac{dZ^*}{d\lambda} = \frac{dZ^*}{d\sigma} + \frac{dZ^*}{d\tau} =$

$$Z^*[\, p^1 P^{\Pi}(p^1, d^1) - d^1 P^{\Delta}(p^1, d^1) - \frac{\partial d^1}{\partial \lambda}] + (1-Z^*)[\, \bar{p}^1 \bar{P}^{\Pi}(p^1, d^1) - \bar{d}^1 \bar{P}^{\Delta}(p^1, d^1) - \frac{\partial \bar{d}^1}{\partial \lambda}] .$$

A sufficient condition for this expression to be positive (negative) is that estimates of P^{Π} and $\bar{P}^{\Pi}$ are both sufficiently high (low).

13. These results differ from the results in Shavell [1982, pp. 60-61], where the litigation costs are held constant. Then it is seen that since the defendant's expenditures are constant, the propensity to litigate increases

as the losing defendant pays a larger portion of the plaintiff's legal costs, i.e., the plaintiff will bring suit more frequently in the system favoring the plaintiff [$\sigma=1,\tau=0$] than under the American System [$\sigma=\tau=0$]. Similarly, he has shown that when the defendant's costs are constant, the propensity to bring suit is decreases as τ increases, i.e., the propensity to litigate is higher under the American system than under the system favoring the defendant, [$\sigma=0,\tau=1$]. The effect of a change in λ is similar to the result in Shavell. He also shows that with litigation costs fixed, the change in the propensity to litigate depends on the plaintiff's estimate of the probability of winning. If the plaintiff's estimate of this probability is above (below) some critical level, then the frequency of suit is higher (lower) under the American system than under the British system.

14. These results are analogous to the results in Shavell [1982] and Simon [1981].

15. The second term on the right hand side of [6.8] can be rewritten as: $E\left[\alpha[1-G(Z^*)]\frac{dT}{d\sigma} - \beta[1-\bar{G}(Z^*)]\frac{d\bar{T}}{d\sigma}\right]$. From the definition of defective output and the information available about the quality of the output, we know that $\alpha>\beta$ and $G(Z^*)<\bar{G}(Z^*)$ for all Z^*. Since $\frac{dET}{d\sigma} > \frac{dE\bar{T}}{d\sigma}$, whenever $\frac{d\pi}{d\sigma} > \frac{d\bar{\pi}}{d\sigma}$, the second term on the right hand side is positive, and precaution is an increasing function of σ.

16. By following the same procedure as in the text, we see that the manufacturer's precaution will increase when τ increases if:

$$E\left[\frac{\partial Z^{*1}}{\partial\tau}\,[\alpha T(\lambda)g(Z^{*1})-\beta\bar{T}(\lambda)\bar{g}(Z^{*1})]\right] < E\left[\alpha[1-G(Z^{*1})]\frac{\partial T}{\partial\tau} - \beta[1-\bar{G}(Z^{*1})]\frac{\partial\bar{T}}{\partial\tau}\right].$$

The left hand side is the reduction in the manufacturer's relative cost of defective output due to the reduction in the plaintiff's propensity to bring

suit and the right hand side is the increase in the difference in the expected liability costs for defective and non-defective output. He will increase his level of precaution only if the second effect dominates.

17. It is straightforward to show that the manufacturer's precaution is an increasing function of λ if and only if:

$$E\left[\frac{\partial Z^{*1}}{\partial \lambda}\left[\alpha T(\lambda)g(Z^{*1})-\beta\bar{T}(\lambda)\bar{g}(Z^{*1})\right]\right] < E\left[\alpha[1-G(Z^{*1})]\frac{\partial T}{\partial \lambda} - \beta[1-\bar{G}(Z^{*1})]\frac{\partial \bar{T}}{\partial \lambda}\right].$$

The left hand side gives the change in the difference between the cost of defective and non-defective output when the propensity to bring suit changes. The right hand side is the change in this difference when the producer's expected costs change due to a change in the proportion of legal costs paid by the losing party. This is positive if the increase in the manufacturer's costs is higher for defective than non-defective output. This will depend on the level of legal expenditures for defective and non-defective output. If the plaintiff's (defendant's) expenditures are higher (lower) for defective output than non-defective output, if $P^{\Pi} > \bar{P}^{\Pi}$, and if the plaintiff's expenditures increase more when output is defective, we see that the effect of a change in relative costs is to increase the producer's precaution.

The producer will increase his precaution if the plaintiff increases his propensity to bring suit or if the plaintiff decreases his propensity to bring suit, but the effect of the change in relative costs is greater than the effect of the change in the propensity to bring suit.

18. By differentiating with respect to Z^*, we see that the right hand side of [F.11] is a decreasing function of Z^* if $\frac{\partial ES}{\partial\sigma} \quad \frac{\partial E\bar{S}}{\partial\sigma}$. This means that if $Z^{*1} > Z^{*2}$, the fall in the critical probability of defect due to a rise in σ is lower in case 2 than in case 1. Sufficient conditions are that: $\pi > \bar{\pi}$, $P^{\Pi} > \bar{P}^{\Pi}$ and $\frac{\partial\delta}{\partial\sigma} > \frac{\partial\bar{\delta}}{\partial\sigma}$.

Similarly, $-\frac{\partial Z^{*1}}{\partial\tau} > -\frac{\partial Z^{*2}}{\partial\tau}$ whenever $\frac{\partial ES}{\partial\tau} > \frac{\partial E\bar{S}}{\partial\tau}$. Sufficient conditions for this inequality are that $\delta < \bar{\delta}$, $P^{\Pi} > \bar{P}^{\Pi}$ and $\frac{\partial\bar{\delta}}{\partial\tau} > \frac{\partial\delta}{\partial\tau}$. In addition, when λ increases, the increase in the propensity to bring suit in lower in case 2 than in case 1 when the above assumptions hold.

19. When the assumptions of Proposition 12 hold, we see that $E\left[\alpha[1-G(Z^{*1})]\frac{\partial T}{\partial\tau} - \beta[1-\bar{G}(Z^{*1})]\frac{\partial\bar{T}}{\partial\tau}\right]$ is a decreasing function of the plaintiff's critical probability of defect, Z^*. Since Z^{*2} is less than Z^{*1}, we see that the effect of a change in relative costs is lower in case 2 than in case 1. In addition, we see that when the critical probability of defect increases with an increase in τ, the effect of the decrease in the propensity to bring suit is lower in case 2 than in case 1.

Appendix A: Notation

In this paper, I have used the following notation:

x producer precaution, measured in dollars per unit of output
$m(x)$ the probability of defect, D
$1-m(x)$ the probability the product is not defective, N
α the probability that a defective unit will cause an accident
β the probability that a non-defective unit will cause an accident
C the cost of an accident

π the plaintiff's legal expenditures
δ the defendant's legal expenditures
$P^{\Pi}(\pi,\delta)$ the probability the plaintiff will win if the product is defective
$\bar{P}^{\Pi}(\pi,\delta)$ the probability the plaintiff will win if the product is not defective
$P^{\Delta}(\pi,\delta)$ and $\bar{P}^{\Delta}(\pi,\delta)$ the probability the defendant will win given product quality
$\Pi(\delta)$, $\bar{\Pi}(\delta)$ the plaintiff's reaction function, given product quality
$\Delta(\pi)$, $\bar{\Delta}(\pi)$ the defendant's reaction function, given product quality

λ the proportion of winning party's legal costs paid by the losing party
σ the proportion of the plaintiff's legal costs paid by a losing defendant
τ the proportion of the defendant's legal costs paid by a losing plaintiff

$S,\bar{S}$ the plaintiff's expected net award, given product quality
$T,\bar{T}$ the defendant's expected cost of trial, given product quality

$U(X)$ the risk averse plaintiff's von Neumann-Morgenstern utility function
r the plaintiff's measure of risk aversion
$\Sigma,\bar{\Sigma}$ the risk averse plaintiff's expected utility if suit is brought, given product quality
y the plaintiff's income

Z the plaintiff's estimate of the probability of defect
Z^* the plaintiff's critical probability of defect, above which the plaintiff will bring suit
Y the defendant's estimate of the probability of defect
$\tilde{Z}(Y)$ the plaintiff's critical probability of defect, above which the case will go to trial

$d^1,\bar{d}^1$ the plaintiff's estimate of the defendant's equilibrium legal expenditures, given product quality
$p^1,\bar{p}^1$ the plaintiff's estimate of his equilibrium legal expenditures, given product quality
$d^2,\bar{d}^2,p^2,\bar{p}^2$ the defendant's estimates of expenditures, given product quality

Appendix B: Proofs

Proof of Proposition 1: The plaintiff's first order conditions under the American and English systems can be rewritten as:

[2.2A] $P^{\Pi}_{\pi}(\pi,\delta) = 1/C$, under the American System, and

[2.6A] $P^{\Pi}_{\pi}(\pi,\delta) = P^{\Delta}(\pi,\delta)/[C+\pi+\delta]$, under the English system.

Since the right hand side (RHS) of [2.2A] is always greater than the RHS of [2.6A] and since there are diminishing returns to legal services, $P^{\Pi}_{\pi\pi} < 0$, we see that, given δ, the plaintiff will always purchase more legal services under the English system than under the American system.

Similarly, by comparing conditions [2.4] and [2.8], it can be shown that, given any level of plaintiff expenditures, the defendant will always purchase more legal services under the English system than under the American system. Q.E.D.

Proof of Proposition 2: A more general result will be proven. It is shown below that under the general system described above, the plaintiff's equilibrium legal expenditures are an increasing function of λ if the product is defective. The defendant's equilibrium legal expenditures are shown to be an increasing function of λ if the product is not defective.

By totally differentiating the equilibrium conditions for the general system, [See Appendix C], we solve for the change in the plaintiff's equilibrium expenditures when the system changes:

$$[B2.1] \quad \frac{d\pi}{d\lambda} = - \frac{T_{\delta\delta}\left[P^{\Pi}_{\pi}(\pi,\delta)[\pi+\delta] + P^{\Pi}(\pi,\delta)\right] - A\left[P^{\Pi}_{\delta}(\pi,\delta)[\pi+\delta] - P^{\Delta}(\pi,\delta)\right]}{S_{\pi\pi}T_{\delta\delta} - A^2},$$

where: $A = P^{\Pi}_{\pi\delta}(\pi,\delta)\left[C+\lambda(\pi+\delta)\right] + \lambda[P_{\pi} + P_{\delta}]$.

Clearly, the denominator of [B2.1] is negative when the second order conditions hold. Since, $P^{\Pi}_{\pi}(\pi,\delta)[\pi+\delta]+P^{\Pi}$ is positive, and $P^{\Pi}_{\delta}(\pi,\delta)[\pi+\delta]-P^{\Delta}$ is negative, and since A is positive when the product is defective, the plaintiff's equilibrium expenditures increase when λ increases if the product is defective.

Similarily, if the product is not defective, it can be shown that the defendant's equilibrium expenditures are an increasing function of the proportion of legal costs paid by the losing party, i.e.

$$\text{[B2.2]} \quad \frac{d\bar{\delta}}{d\lambda} = - \frac{\bar{S}_{\pi\pi}\left[\bar{P}^{\Pi}_{\delta}(\bar{\pi},\bar{\delta})[\bar{\pi}+\bar{\delta}] - \bar{P}^{\Delta}(\bar{\pi},\bar{\delta})\right] - \bar{A}\left[\bar{P}^{\Pi}_{\pi}(\bar{\pi},\bar{\delta})[\bar{\pi}+\bar{\delta}] + \bar{P}^{\Pi}(\bar{\pi},\bar{\delta})\right]}{\bar{S}_{\pi\pi}\,\bar{T}_{\delta\delta} - \bar{A}^{2}} > 0,$$

when the product is not defective, i.e., when $\bar{A}$ is negative. Q.E.D.

<u>Proof of Proposition 3:</u> If the product is defective, we can solve for the effect of a change in the proportion of costs shifted on the probability that the plaintiff will win:

$$\text{[B2.3]} \quad \frac{dP^{\Pi}}{d\lambda} = P^{\Pi}_{\pi}\frac{d\pi}{d\lambda} + P^{\Pi}_{\delta}\frac{d\delta}{d\lambda}$$

$$= - \frac{\left[P^{\Pi}_{\delta}[\pi+\delta]-P^{\Delta}\right]\left[P^{\Pi}_{\delta}S_{\pi\pi}-P^{\Pi}_{\pi}A\right] + \left[P^{\Pi}_{\pi}[\pi+\delta]+P^{\Pi}\right]\left[P^{\Pi}_{\pi}T_{\delta\delta}-P^{\Pi}_{\delta}A\right]}{S_{\pi\pi}T_{\delta\delta} - A^{2}}.$$

The denominator of [B2.3] is negative when the second order conditions

hold, and if the product is defective, i.e., if A is positive, the last term of the numerator is positive. The first term of the numerator can be rewritten as:

$$[B2.4] \quad [P^{\Pi}_{\delta}[\pi+\delta]-P^{\Delta}][(P^{\Pi}_{\delta}P^{\Pi}_{\pi\pi} - P^{\Pi}_{\pi}P^{\Pi}_{\pi\delta})[C+\lambda(\pi+\delta)] + \lambda P^{\Pi}_{\pi}P^{\Pi}_{\delta} - \lambda P^{\Pi 2}_{\pi}].$$

The first term of [B2.4] is negative, and the second term is also negative if $-\frac{P^{\Pi}_{\pi\delta}}{P^{\Pi}_{\pi\pi}} > -\frac{P^{\Pi}_{\delta}}{P^{\Pi}_{\pi}}$, proving the first half of the proposition.

If the product is not defective, the effect of a change in λ on the probability that the plaintiff will win is:

$$[B2.5] \quad \frac{d\bar{P}^{\Pi}}{d\lambda} = - \frac{[\bar{P}^{\Pi}_{\delta}[\bar{\pi}+\bar{\delta}]-\bar{P}^{\Delta}][\bar{P}^{\Pi}_{\delta}\bar{S}_{\pi\pi}-\bar{P}^{\Pi}_{\pi}\bar{A}] + [\bar{P}^{\Pi}_{\pi}[\bar{\pi}+\bar{\delta}]+\bar{P}^{\Pi}][\bar{P}^{\Pi}_{\pi}\bar{T}_{\delta\delta}-\bar{P}^{\Pi}_{\delta}\bar{A}]}{\bar{S}_{\pi\pi}\bar{T}_{\delta\delta} - \bar{A}^{2}}.$$

The denominator is negative when the second order conditions hold, and the first term of the numerator is positive when the product is not defective. The second term of the numerator can be rewritten as:

$$[B2.6] \quad [\bar{P}^{\Pi}_{\pi}[\bar{\pi}+\bar{\delta}]+\bar{P}^{\Pi}][(\bar{P}^{\Pi}_{\pi}\bar{P}^{\Pi}_{\delta\delta} - \bar{P}^{\Pi}_{\delta}\bar{P}^{\Pi}_{\pi\delta})[C+\lambda(\bar{\pi}+\bar{\delta})] + \lambda\bar{P}^{\Pi}_{\pi}\bar{P}^{\Pi}_{\delta} - \lambda\bar{P}^{\Pi 2}_{\pi}].$$

The first term of [B2.6] is positive, and the second term is negative if $\bar{P}^{\Pi}_{\pi}\bar{P}^{\Pi}_{\delta\delta} < \bar{P}^{\Pi}_{\delta}\bar{P}^{\Pi}_{\pi\delta}$, proving the proposition. Q.E.D.

<u>Proof of Proposition 4:</u> By rearranging equation [3.2], we see that the plaintiff's reaction function can be rewritten as:

$$[B3.1] \quad P^{\Pi}_{\pi} = (1-\sigma)P^{\Pi}\frac{U'(W)}{U(W)-U(L)} + P^{\Delta}\frac{U'(L)}{U(W)-U(L)} = P^{\Delta}\frac{U'(L)}{U(W)-U(L)},$$

where $W=y-(1-\sigma)\pi$ and $L=y-C-\pi-\tau\delta$. When $\sigma=1$, the right hand side of [B3.1] is

an increasing function of the plaintiff's risk aversion, since $\frac{U(W)-U(L)}{U'(L)}$ decreases as the plaintiff's risk aversion increases [Pratt, p. 129], and therefore, since $P_{\pi\pi}$ is negative, as the plaintiff's risk aversion increases, he will lower his litigation costs, given δ.

When the product is defective, as the plaintiff becomes more risk averse, the equilibrium legal expenditures of the plaintiff fall, and the defendant's expenditures rise. It is clear that as the plaintiff's risk aversion, r, increases, the probability that the plaintiff will win falls:

$$[B3.2'] \qquad \frac{dP^{\Pi}}{dr} = P^{\Pi}_{\pi}\frac{d\pi}{dr} + P^{\Pi}_{\delta}\frac{d\delta}{dr} < 0.$$

If the product is not defective, as the plaintiff's risk aversion increases, the equilibrium expenditures move to the left along $\Delta(\pi)$. Using the second assumption in Proposition 3, we see that:

$$[B3.3] \qquad \frac{d\bar{P}^{\Pi}}{dr} = \left[\bar{P}^{\Pi}_{\pi} + \bar{P}^{\Pi}_{\delta}\,\bar{\Delta}'(\bar{\pi})\right]\frac{d\bar{\pi}}{dr} = \left[\bar{P}^{\Pi}_{\pi} - \bar{P}^{\Pi}_{\delta}\,\frac{\bar{T}_{\pi\delta}}{\bar{T}_{\delta\delta}}\right]\frac{d\bar{\pi}}{dr} > 0,$$

<u>Proof of Proposition 5:</u> If the plaintiff is risk averse, his reaction curve is given by the first order condition:

$$[B3.4] \qquad \Sigma_{\pi} = P^{\Pi}_{\pi}\left[U(W)-U(L)\right] - (1-\sigma)P^{\Pi}\,U'(W) - P^{\Delta}\,U'(L).$$

The second order condition is : $\Sigma_{\pi\pi} < 0$. The plaintiff's reaction function will shift to the right with an increase in σ, if $-\Sigma_{\pi\sigma}/\Sigma_{\pi\pi}$ is positive. This is the case if $\Sigma_{\pi\sigma}$ is positive. By differentiating equation [B3.4] with respect to σ, and simplifying, we see that:

$$[B3.5] \qquad \frac{\Sigma_{\pi\sigma}}{U'(W)} = \left[\pi P_{\pi} + P^{\Pi}\right] - \pi(1-\sigma)P^{\Pi}\,\frac{U''(W)}{U'(W)} = S_{\pi\sigma} + \pi(1-\sigma)P^{\Pi}\,r(W),$$

where $r(W)$ is the plaintiff's risk aversion at W and S is the expected net award. If $r(W)$ is non-negative, it is clear that the right hand side of [B3.6] is positive, and therefore, the risk averse plaintiff's reaction curve shifts to the right with an increase in σ, proving the first half of the proposition.

The plaintiff's reaction function will shift to the right with an increase in τ if $\Sigma_{\pi\tau}$ is positive. By differentiating [C3.5] and simplifing, we see that:

$$[B3.7] \quad \frac{\Sigma_{\pi\tau}}{U'(L)} = \delta P^{\Pi}_{\pi} + \delta P^{\Delta} \frac{U''(L)}{U'(L)} = S_{\pi\tau} - \delta P^{\Delta} r(L),$$

where $r(L)$ is the plaintiff's risk aversion at L. Since $S_{\pi\tau}$ is positive, we see that the plaintiff's reaction function will shift to the right only if $r(L)$ is less than some critical level, $R{*}=P^{\Pi}_{\pi}/P^{\Delta}$, proving the second half of the proposition. Q.E.D.

Appendix C: Derivation of Effects of Changes in the proportions σ and τ

When the proportion of legal costs paid by the losing defendant, σ, is not necessarily equal to the proportion paid by a losing plaintiff, τ, the risk neutral plaintiff will maximize his expected net award. If the product is defective, his optimization is:

$$[C.1] \quad \max_{\pi} \quad S = P^{\Pi}(\pi,\delta)[C-(1-\sigma)\pi] - P^{\Delta}(\pi,\delta)[\pi+\tau\delta].$$

This first order condition is the first equilibrium condition:

$$[C.2] \quad S_{\pi} = P^{\Pi}_{\pi}(\pi,\delta)\left[C+\sigma\pi+\tau\delta\right] - \left(1-\sigma P^{\Pi}(\pi,\delta)\right) = 0.$$

Similarly, in equilibrium, the defendant will minimize his expected costs, given the plaintiff's expenditures and the cost-allocation system in effect:

$$[C.3] \quad \min_{\delta} \ T = P^{\Pi}(\pi,\delta)[C+\delta+\sigma\pi] + P^{\Delta}(\pi,\delta)\left(1-\tau\right)\delta.$$

The first order condition for this minimization gives the defendant's reaction function:

$$[C.4] \quad T_{\delta} = P^{\Pi}_{\delta}\left[C+\sigma\pi+\tau\delta\right] + 1-\tau P^{\Delta}(\pi,\delta) = 0.$$

By totally differentiating the equilibrium conditions, we see that:

$$[C.5] \quad \begin{bmatrix} S_{\pi\pi} & S_{\pi\delta} \\ T_{\pi\delta} & T_{\delta\delta} \end{bmatrix} \begin{bmatrix} d\pi \\ d\delta \end{bmatrix} = - \begin{bmatrix} S_{\pi\sigma}d\sigma + S_{\pi\tau}d\tau \\ T_{\delta\sigma}d\sigma + T_{\delta\tau}d\tau \end{bmatrix},$$

where $T_{\pi\delta} = S_{\pi\delta} = A = P^{\Pi}_{\pi\delta}[C+\sigma\pi+\tau\delta] + \sigma P^{\Pi}_{\delta} + \tau P^{\Pi}_{\pi}$,

and where:

$$S_{\pi\sigma} = \pi P^{\Pi}_{\pi} + P^{\Pi} > 0, \quad S_{\pi\tau} = \delta P^{\Pi}_{\pi} > 0, \quad T_{\delta\sigma} = \pi P^{\Pi}_{\delta} < 0 \text{ and } T_{\delta\tau} = \delta P^{\Pi}_{\delta} - P^{\Delta} < 0.$$

By Cramer's Rule, we see that:

$$[C.6] \quad \frac{d\pi}{d\sigma} = \frac{\begin{vmatrix} S_{\pi\sigma} & A \\ T_{\delta\sigma} & T_{\delta\delta} \end{vmatrix}}{\begin{vmatrix} S_{\pi\pi} & A \\ A & T_{\delta\delta} \end{vmatrix}} = - \frac{\left[\pi P^{\Pi}_{\pi} + P^{\Pi}\right] T_{\delta\delta} - A\left[\pi P^{\Pi}_{\delta}\right]}{S_{\pi\pi}\, T_{\delta\delta} - A} .$$

The denominator of [C.6] is negative when the S.O.C.'s obtain and the numerator of [C.6] is positive if the output is defective, i.e., if A is positive. Therefore, the equilibrium litigation costs for a risk neutral plaintiff is an increasing function of σ, when the product is defective.

It is also seen that:

$$[C.7] \quad \frac{d\delta}{d\sigma} = \frac{\begin{vmatrix} S_{\pi\pi} & S_{\pi\sigma} \\ A & T_{\delta\sigma} \end{vmatrix}}{S_{\pi\pi} T_{\delta\delta} - A^2} = - \frac{\pi P^{\Pi}_{\delta}\, S_{\pi\pi} - A\left[\pi P^{\Pi}_{\pi} + P^{\Pi}\right]}{S_{\pi\pi}\, T_{\delta\delta} - A^2}$$

The change in the probability of plaintiff winning when the product is defective can be calculated:

$$[C.8] \quad \frac{dP^{\Pi}}{d\sigma} = P^{\Pi}_{\pi} \frac{d\pi}{d\sigma} + P^{\Pi}_{\delta} \frac{d\delta}{d\sigma} = - \frac{\left[P^{\Pi}_{\pi} T_{\delta\delta} - P^{\Pi}_{\delta} A\right]\left[\pi P^{\Pi}_{\pi} + P^{\Pi}\right] + \left[P^{\Pi}_{\delta} S_{\pi\pi} - P^{\Pi}_{\delta} A\right]\left[\pi P^{\Pi}_{\alpha}\right]}{S_{\pi\pi} T_{\delta\delta} - A^2}$$

Using the same procedure as in Proposition 3, it is straightforward to show that the probability that the plaintiff will win in an increasing function of σ, wherever $-\dfrac{P_{\pi\delta}}{P_{\pi\pi}} > \dfrac{P_{\delta}}{P_{\pi}}$.

Similarly, we see that:

$$[C.9] \quad \frac{d\pi}{d\tau} = - \frac{\delta P^{\Pi}_{\pi} T_{\delta\delta} - A[\delta P^{\Pi}_{\delta} - P^{\Delta}]}{S_{\pi\pi} T_{\delta\delta} - A^2} > 0,$$

and that:

$$[C.10] \quad \frac{d\delta}{d\tau} = - \frac{[\delta P^{\Pi}_{\delta} - P^{\Delta}] S_{\pi\pi} - A\delta P^{\Pi}_{\pi}}{S_{\pi\pi} T_{\delta\delta} - A^2}.$$

It is straightforward to show that:

$$[C.11] \quad \frac{dP^{\Pi}}{d\tau} = - \frac{[P^{\Pi}_{\pi} T_{\delta\delta} - P^{\Pi}_{\delta}A][\delta P^{\Pi}_{\pi}] + [P^{\Pi}_{\delta} S_{\pi\pi} - P^{\Pi}_{\pi}A][\delta P^{\Pi}_{\delta} - P^{\Delta}]}{S_{\pi\pi} T_{\delta\delta} - A^2},$$

which is positive whenever $- \frac{P_{\pi\delta}}{P_{\pi\pi}} > \frac{P_{\delta}}{P_{\pi}}$.

Similarly, it is straightforward to show that the following inequalities hold:

$[C.12]$ $\frac{d\bar{\delta}}{d\sigma} > 0$ and $\frac{d\bar{\delta}}{d\tau} > 0$, whenever $\bar{P}^{\Pi}_{\delta\pi} < - C^{-2}$, and

$[C.13]$ $\frac{d\bar{P}^{\Pi}}{d\sigma} < 0$ and $\frac{d\bar{P}^{\Pi}}{d\tau} < 0$, whenever $- \frac{\bar{P}^{\Pi}_{\pi\delta}}{\bar{P}^{\Pi}_{\delta\delta}} > - \frac{\bar{P}^{\Pi}_{\pi}}{\bar{P}^{\Pi}_{\delta}}$.

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